

Advanced Network Technologies

Wireless 2

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IEEE 802.11 Wireless LANs WiFi

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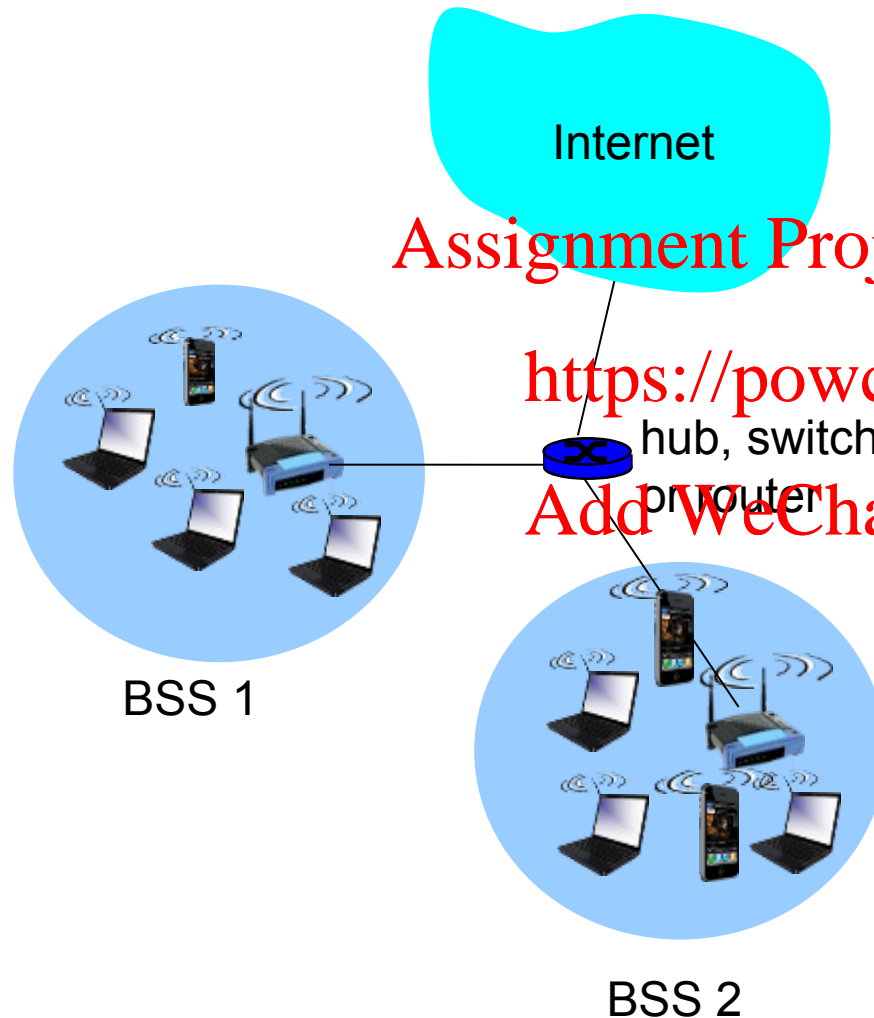
IEEE 802.11 WiFi

IEEE 802.11 standard	Year	Max data rate	Range	Frequency
802.11b	1999	11 Mbps	30m	2.4 Ghz
802.11a	1999	54 Mbps	30m	5 Ghz
802.11g	2003	54 Mbps	30m	2.4 Ghz
802.11n (WiFi 4)	2009	600 Mbps	70m	2.4, 5 Ghz
802.11ac (WiFi 5)	2013	3.47Gbps	70m	5 Ghz
802.11ax (WiFi 6)	2020 (exp.)	14 Gbps	70m	2.4, 5 Ghz
802.11af	2014	35 – 560 Mbps	1 Km	unused TV bands (54-790 MHz)
802.11ah	2017	347Mbps	1 Km	900 Mhz

- all use CSMA/CA for multiple access, and have base-station and ad-hoc network versions



802.11 LAN architecture

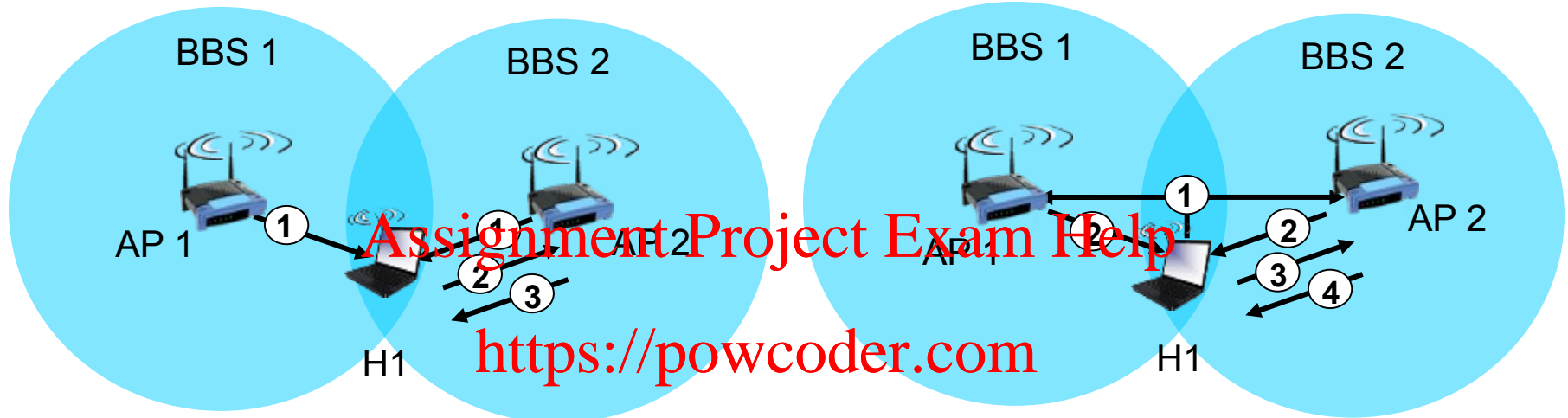


- ❖ wireless host communicates with base station
- ❖ Base station = access point (AP)
- ❖ Basic Service Set (BSS) (aka “cell”) in infrastructure mode contains:
 - wireless hosts
 - access point (AP): base station
 - ad hoc mode: hosts only

- › 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
 - AP admin chooses frequency for AP
 - interference possible, channel can be same as that chosen by neighboring AP!
- › host: must *associate* with an AP
 - scans channels, listening for beacon frames containing AP's name (SSID) and MAC address
 - selects AP to associate with
 - may perform authentication
 - will typically run DHCP to get IP address in AP's subnet



802.11: passive/active scanning

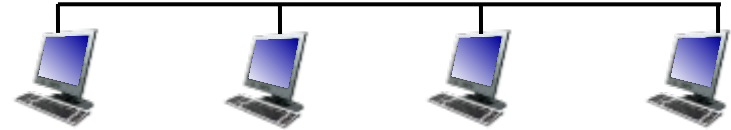


passive scanning:

- (1) beacon frames sent from APs
- (2) association Request frame sent: H1 to selected AP
- (3) association Response frame sent from selected AP to H1

active scanning:

- (1) Probe Request frame broadcast from H1
- (2) Probe Response frames sent from APs
- (3) Association Request frame sent: H1 to selected AP
- (4) Association Response frame sent from selected AP to H1



› collisions *can* occur:

propagation delay means

two nodes may not hear
each other's transmission

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time
↓

› collision: frame transmission
time wasted

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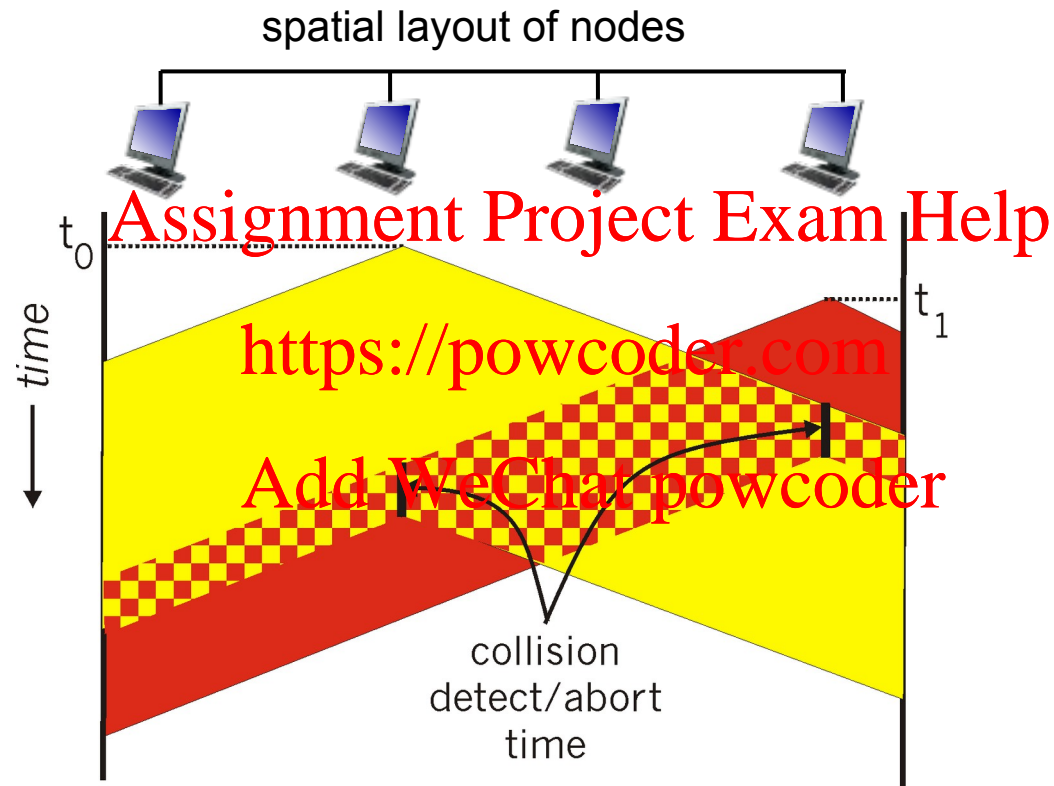
t_1

CSMA/CD:

- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

> collision detection:

- wired LANs: measure signal strengths, compare transmitted, received signals
- Can transmit and sense at the same time
- wireless LANs: received signal strength overwhelmed by local transmission strength
- CSMA-CD cannot be used in wireless LAN



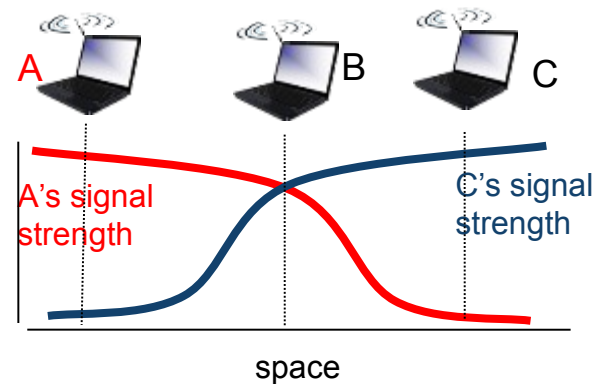
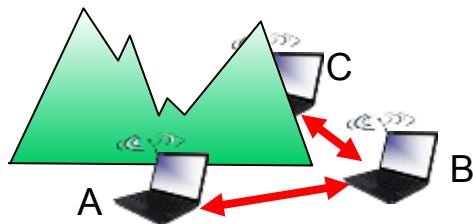
IEEE 802.11: multiple access

> 802.11: no collision detection!

- difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
- can not sense all collisions in any case: hidden terminal, fading
- goal: *avoid collisions*: CSMA/C(ollision)A(voidance)

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IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

1 if sense channel idle for **DIFS** (Distributed inter-frame space) then

transmit entire frame (no CD)

2 if sense channel busy then

start random backoff time

timer counts down while channel idle

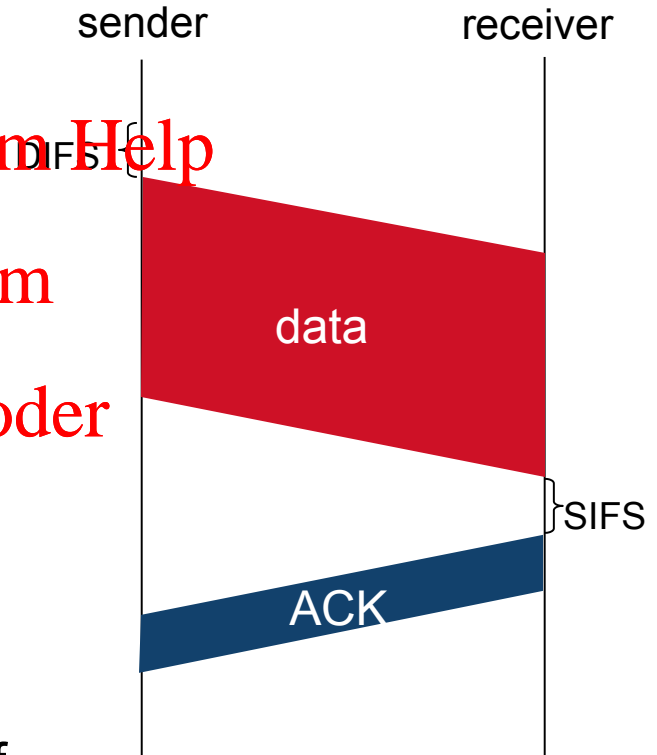
transmit when timer expires

802.11 receiver

- if frame received OK

return ACK after **SIFS** (Shorter inter-frame spacing)

Sender : if no ACK, increase random backoff interval, repeat 2



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- idea:* allow sender to “reserve” channel rather than random access of data frames: avoid collisions of long data frames
- › sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
 - RTSs may still collide with each other (but they're short)
 - › BS broadcasts clear-to-send CTS in response to RTS
 - › CTS heard by all nodes
 - sender transmits data frame
 - other stations defer transmissions

*avoid data frame collisions completely
using small reservation packets!*



Collision Avoidance: RTS-CTS exchange



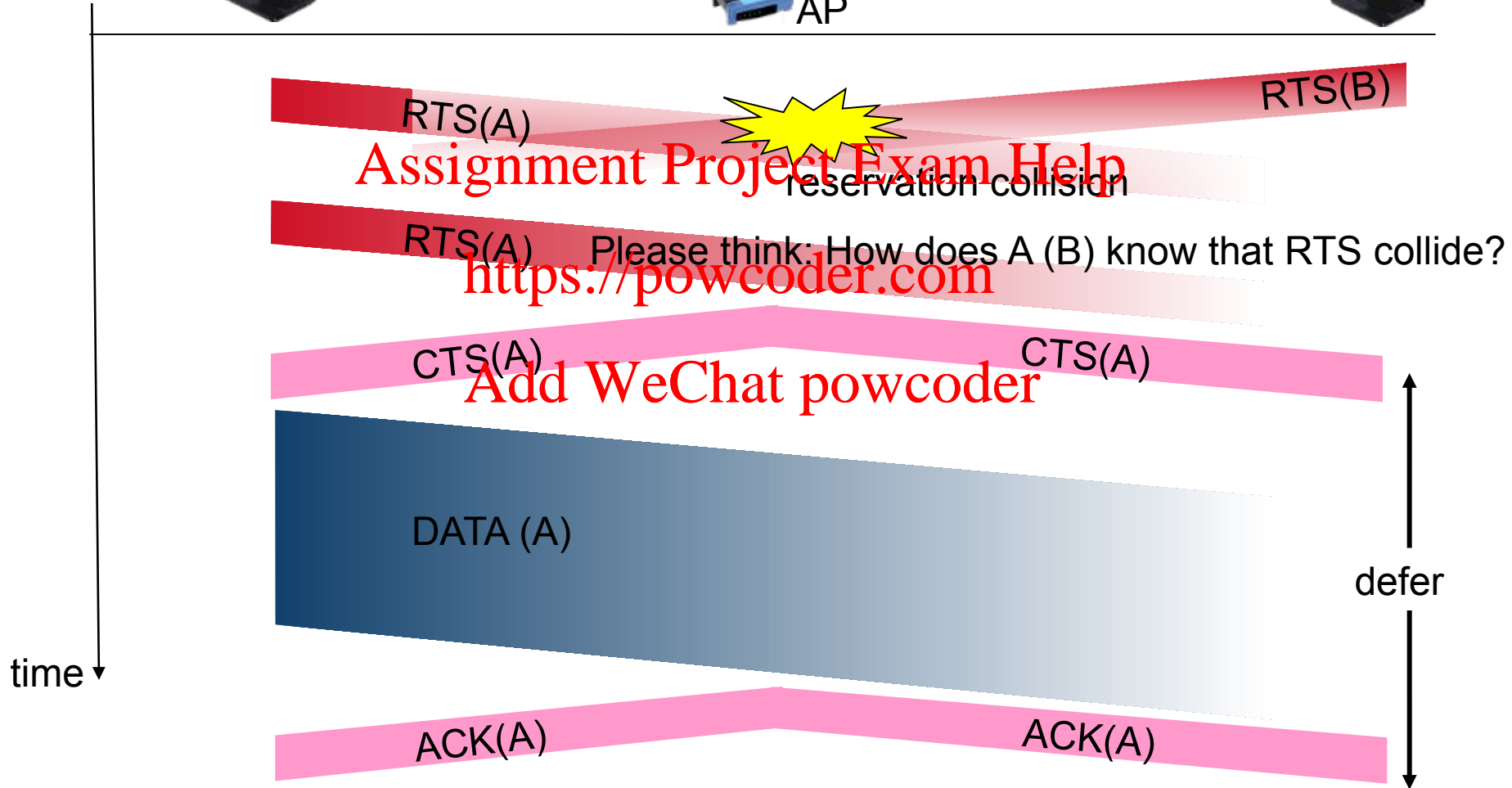
A



AP

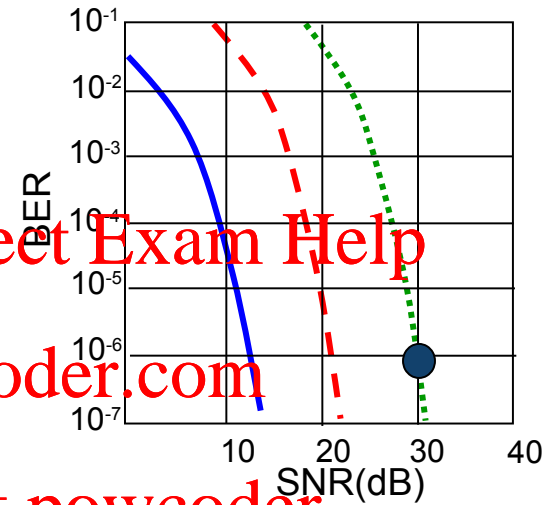
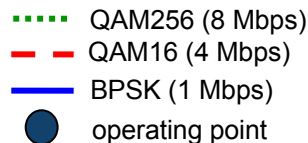


B



Rate adaptation

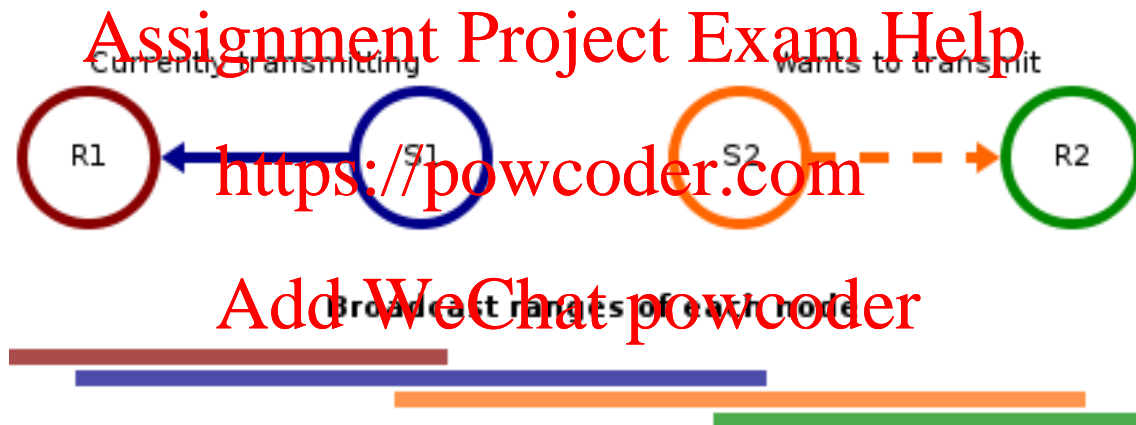
- › base station, mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies



1. SNR decreases, BER increase as node moves away from base station
2. When BER becomes too high, switch to lower transmission rate but with lower BER



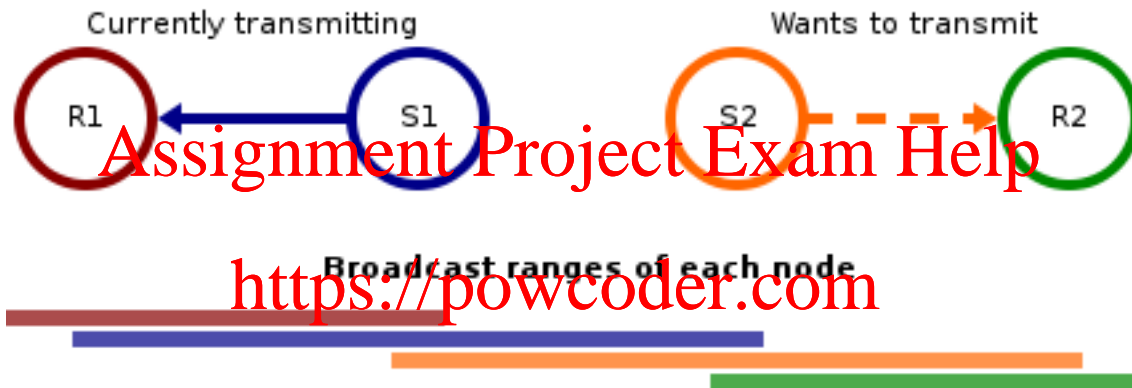
Exposed terminal problem



Source: Wikipedia



Exposed terminal problem



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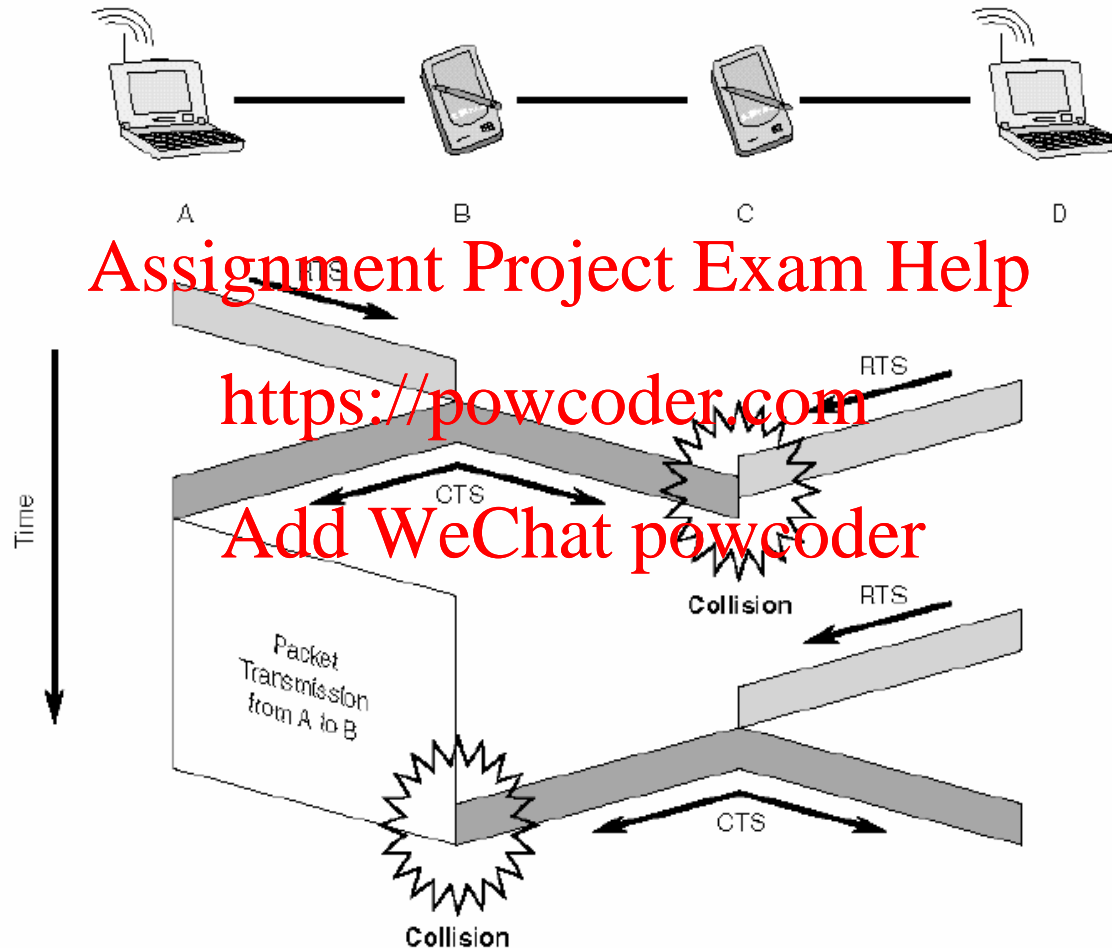
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Ideal: $S1 \rightarrow R1$ and $S2 \rightarrow R2$ simultaneously

However: S2 can sense the carrier of S1 so that it keeps silence



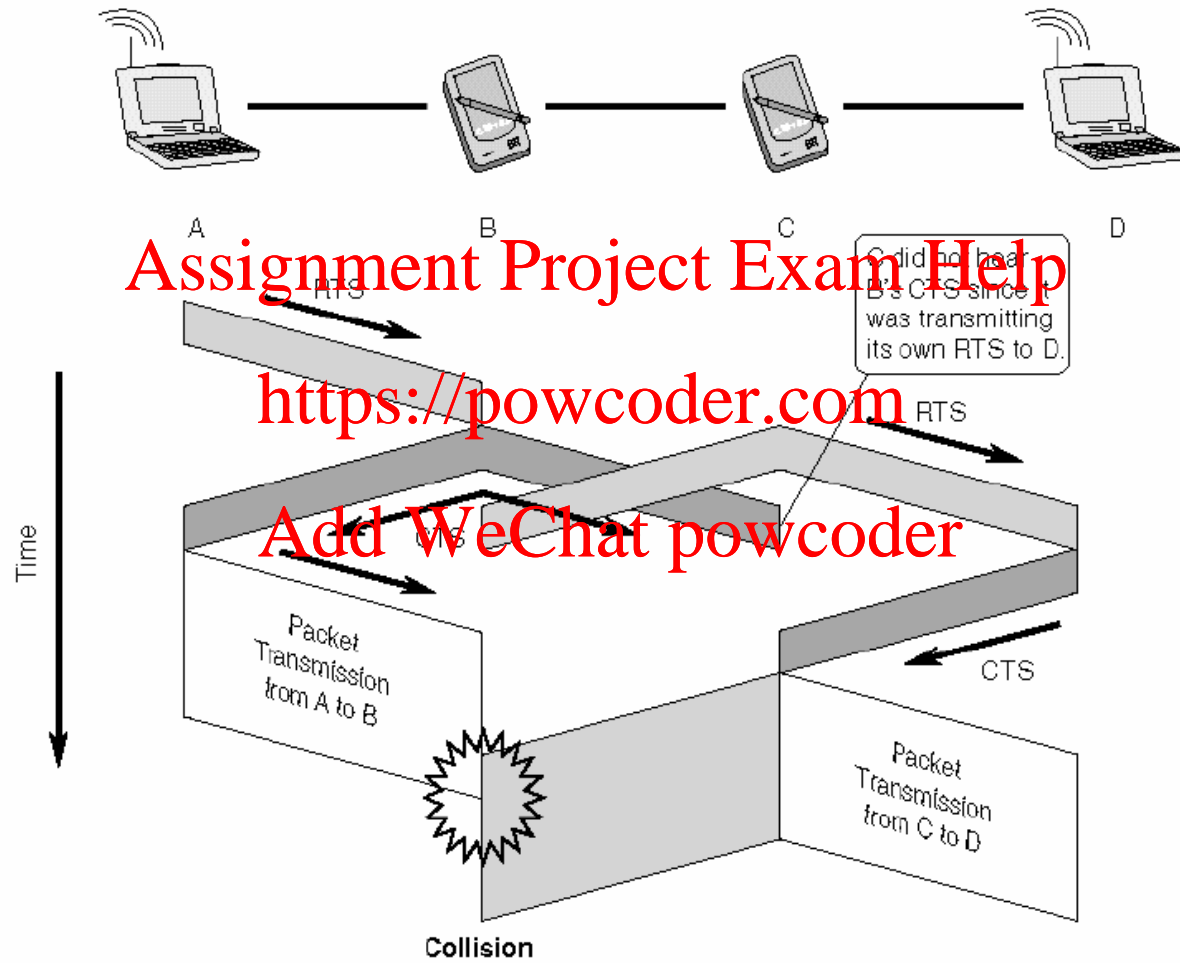
Can RTS-CTS fail? Yes



Source: http://www.cs.jhu.edu/~cs647/mac_lecture_3.pdf



Can RTS-CTS fail? Yes





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Cellular Internet Access Architecture and standards

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Components of cellular network architecture

cell

- ❖ covers geographical region
- ❖ *base station* (BS) analogous to 802.11 AP
- ❖ *mobile users* attach to network through BS
- ❖ *air-interface*: physical and link layer protocol between mobile and BS

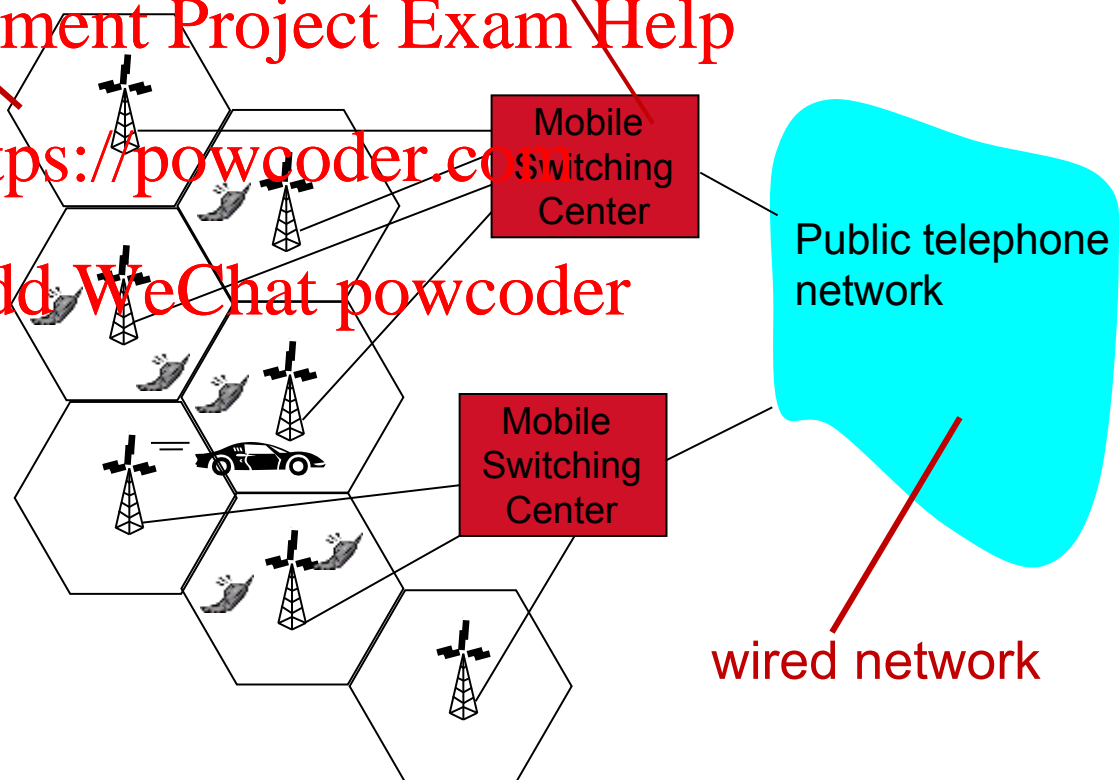
MSC

- ❖ connects cells to wired tel. net.
- ❖ manages call setup (more later!)
- ❖ handles mobility (more later!)

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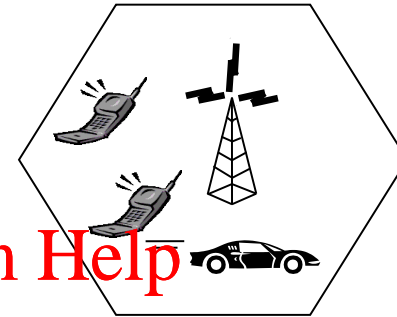


Cellular networks: the first hop

Two techniques for sharing mobile-to-BS radio spectrum

- › **combined FDMA/TDMA**: divide spectrum in frequency channels, divide each channel into time slots

- › **CDMA**: code division multiple access



time slots



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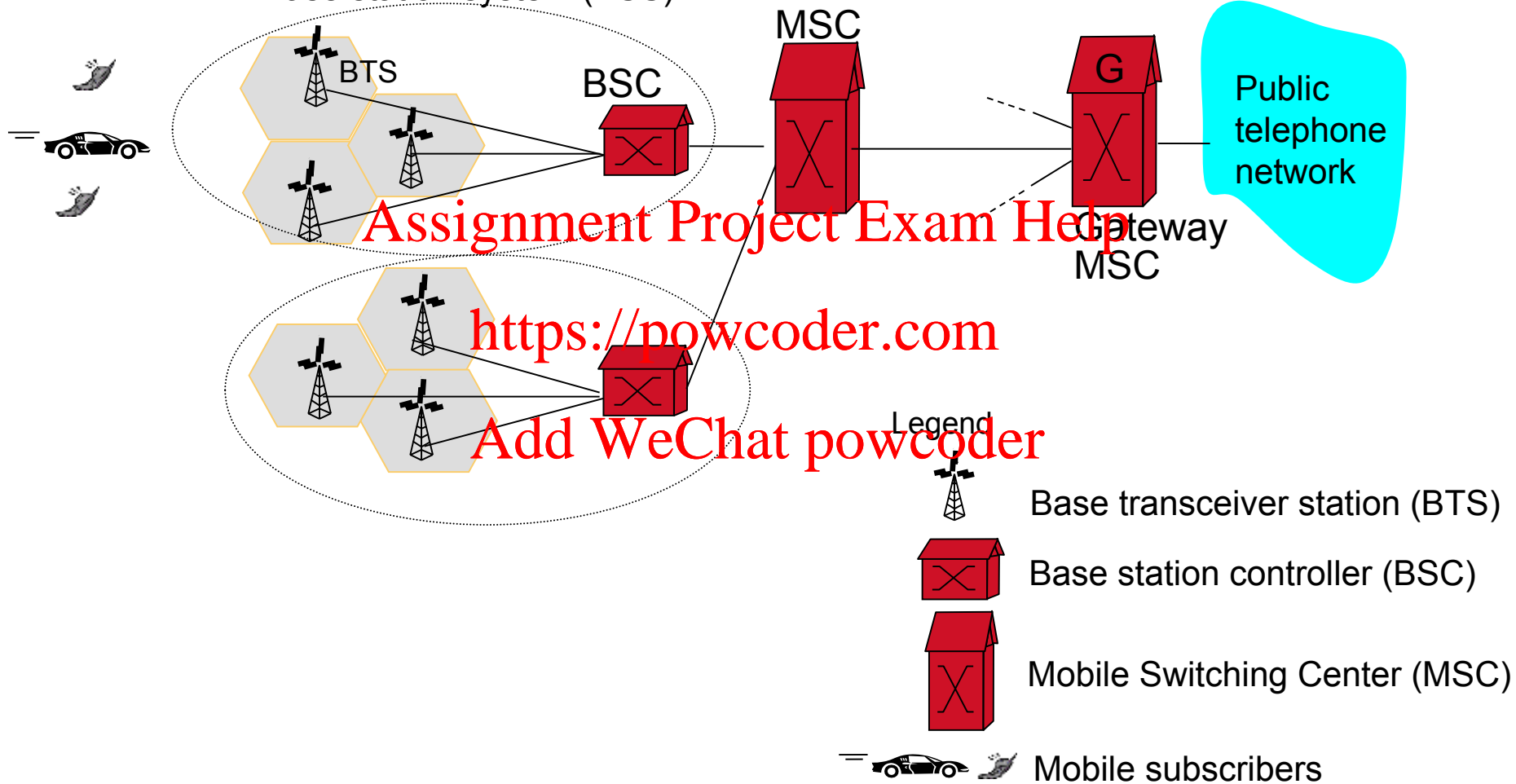
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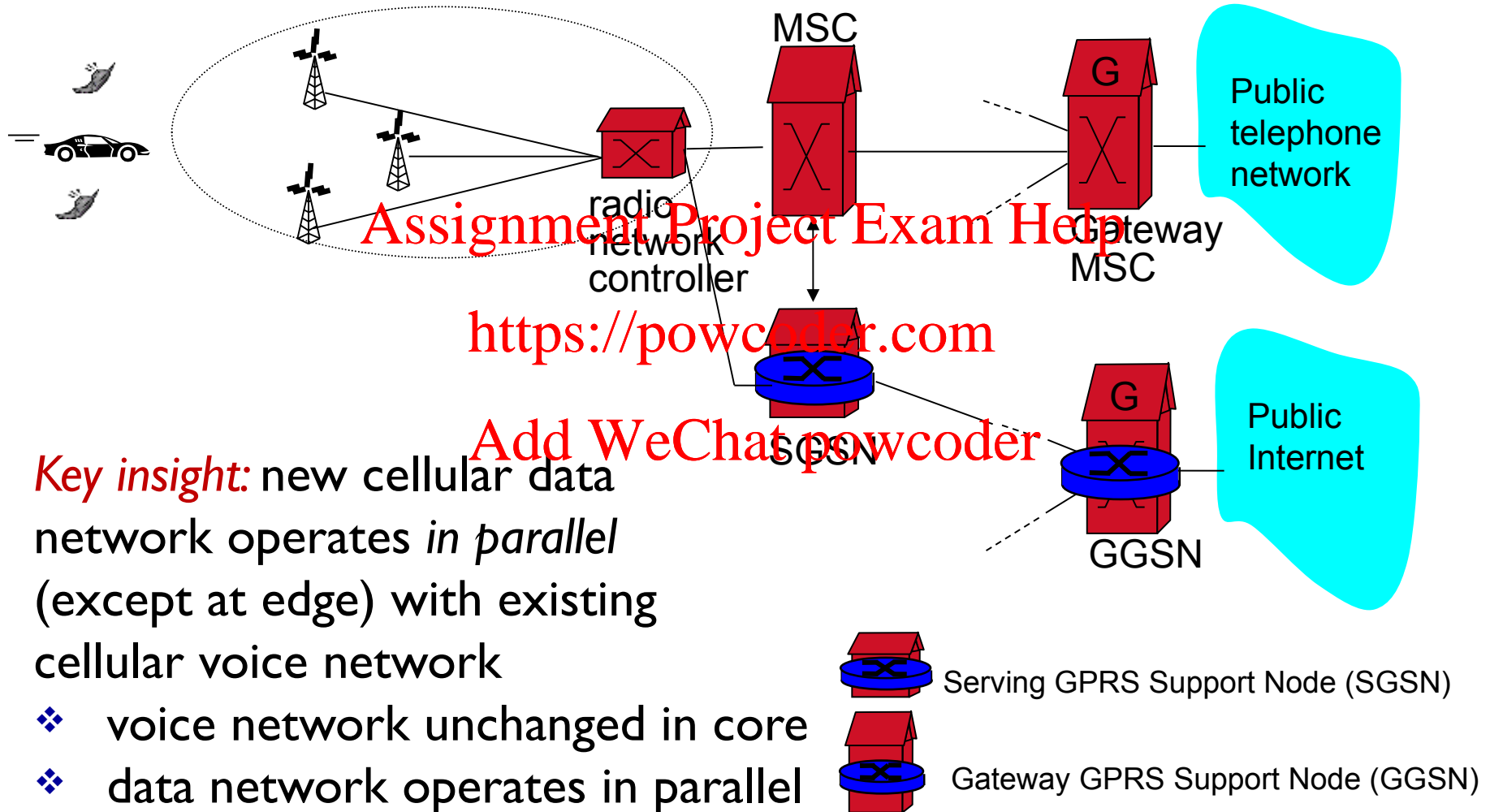
2G (voice) network architecture

Base station system (BSS)





3G (voice+data) network architecture



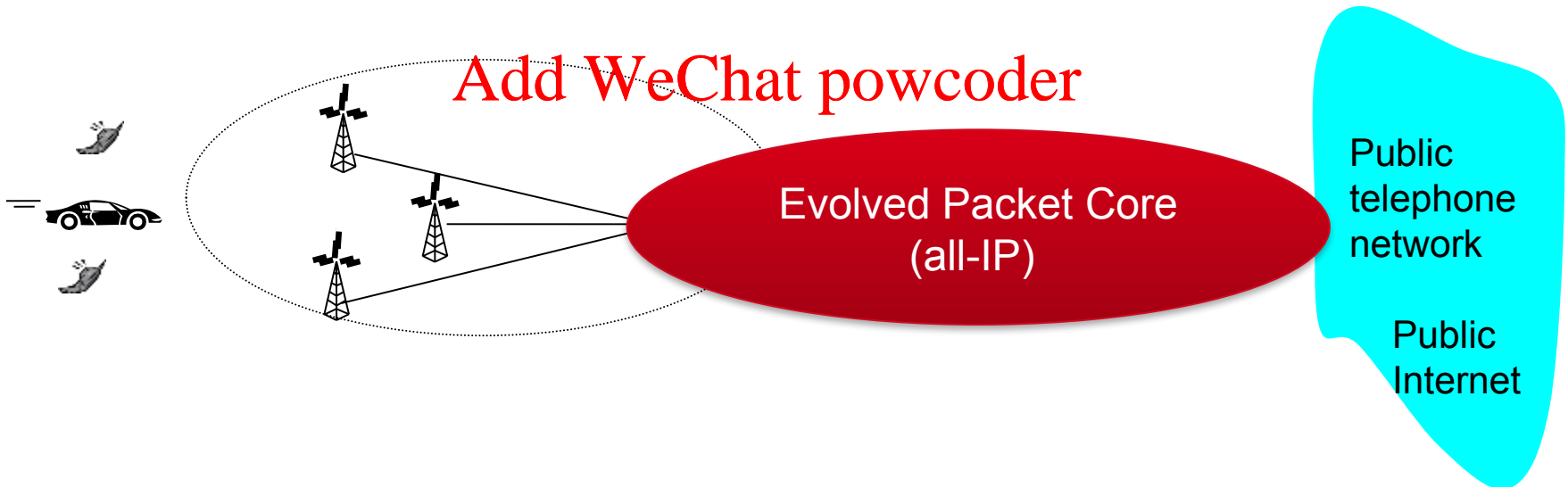
4G: Long-Term Evolution (LTE)

Two important innovations over 3G

1. **Evolved packet core (EPC):** simplified all-IP core network that unifies the cellular circuit-switched voice network and the packet switched cellular data network.

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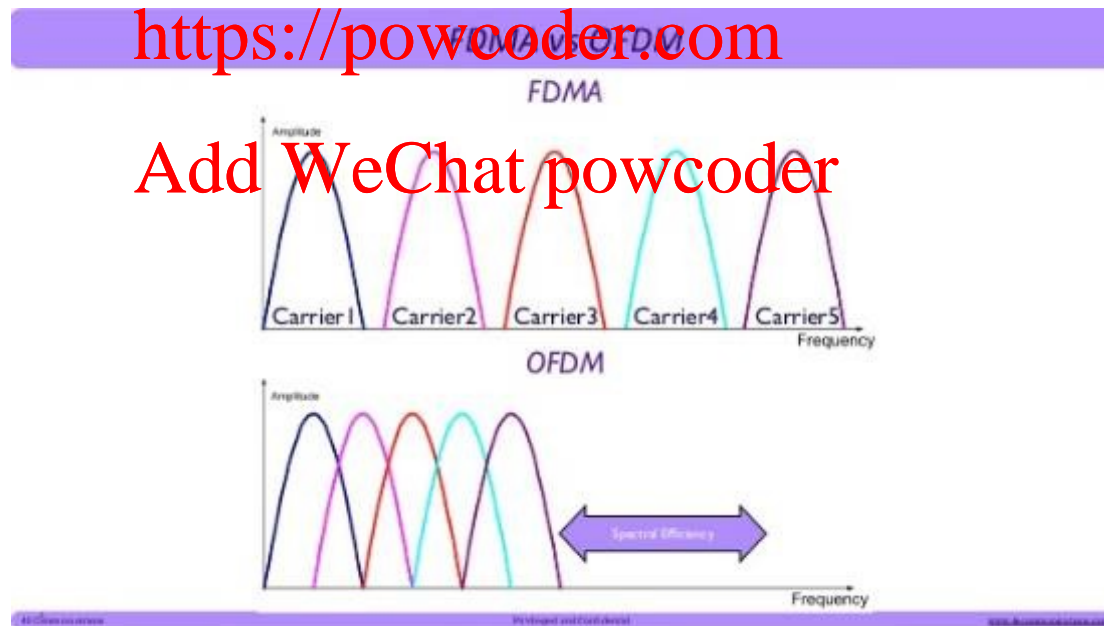
4G: Long-Term Evolution (LTE)

Two important innovations over 3G

2. **LTE Radio Access Networks:** uses a combination of orthogonal frequency-division multiplexing (OFDM) and time division multiplexing.

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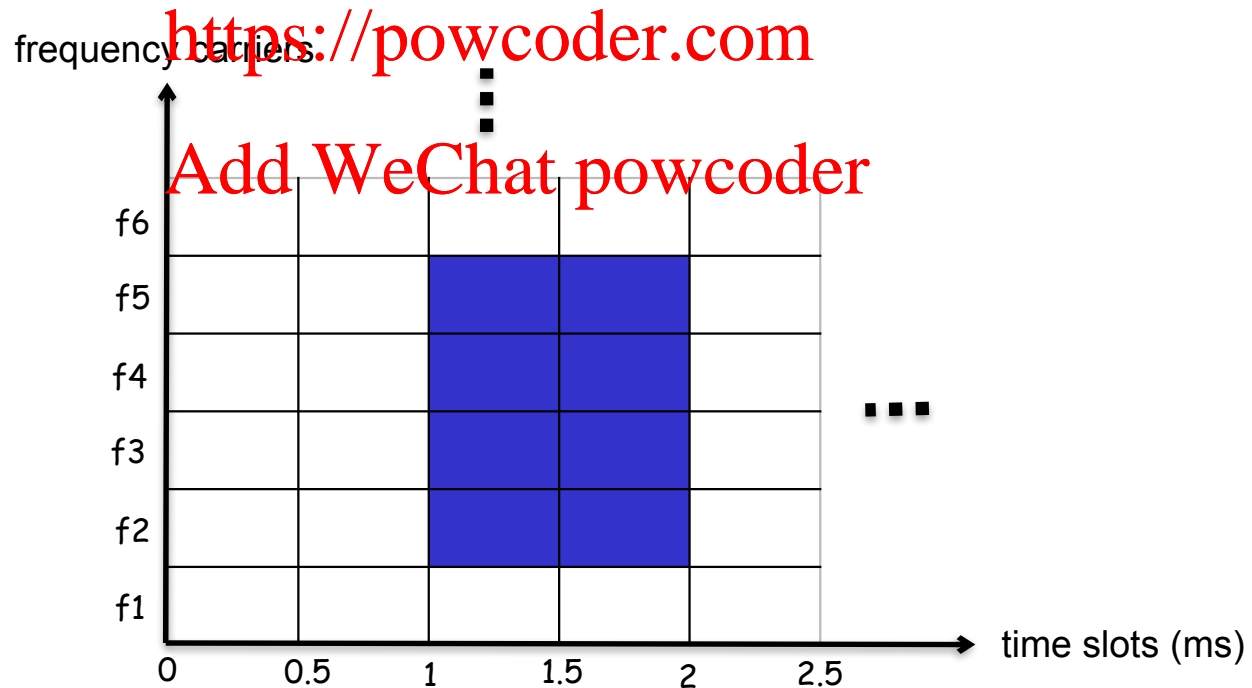
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4G: Long-Term Evolution (LTE)

Two important innovations over 3G

2. **LTE Radio Access Networks:** uses a combination of orthogonal frequency-division multiplexing (OFDM) and time division multiplexing.





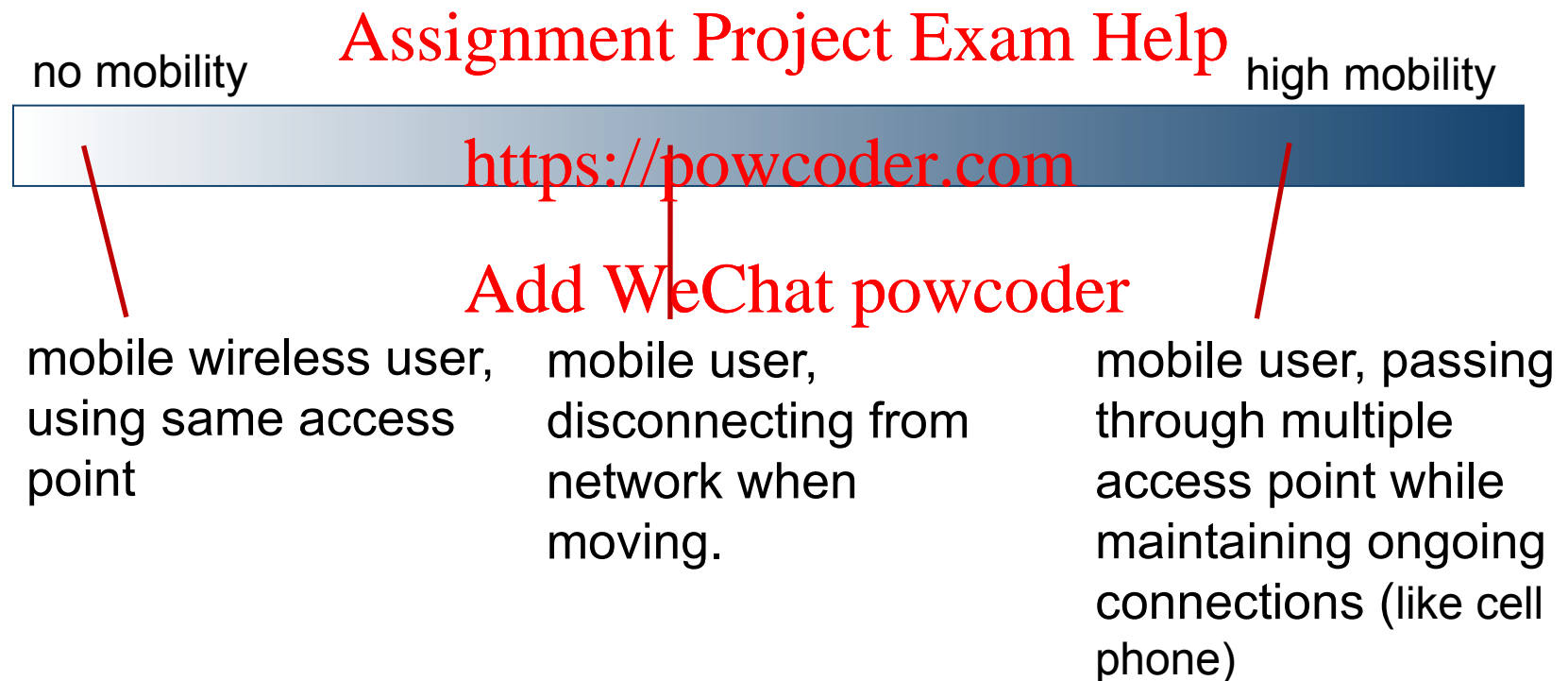
Mobility principles: Addressing and routing to mobile users

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- › spectrum of mobility, from the *network* perspective:



Should Address always remain the same?

- › Mobile phone: the phone number remains the same at all time when you travel

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- › How about IP Address?

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home network: permanent
“home” of mobile
(e.g., 128.119.40/24)

home agent: entity that will
perform mobility functions on
behalf of mobile

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permanent address:
address in home
network, *can always* be
used to reach mobile
e.g., 128.119.40.186





Mobility: more vocabulary

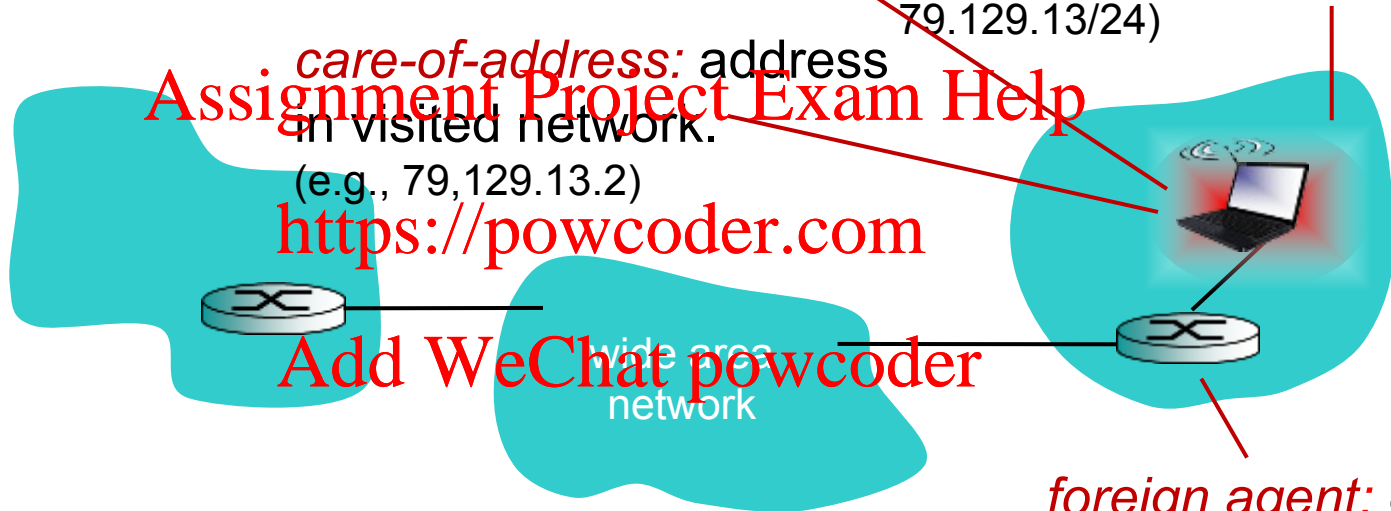
permanent address: remains constant (e.g., 128.119.40.186)

Foreign (visited) network: network in which mobile currently resides (e.g., 79.129.13/24)

care-of-address: address in visited network.
(e.g., 79.129.13.2)

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correspondent: wants to communicate with mobile

foreign agent: entity in visited network that performs mobility functions on behalf of mobile.



How do you contact a mobile friend:

Consider friend frequently changing addresses, how do you find her?

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› search all phone books? <https://powcoder.com>

› call her parents?

› expect her to let you know where he/she is?

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- › *let routing handle it*: routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.
 - routing tables indicate where each mobile located
 - no changes to end-systems
- › *let end-systems handle it*:
 - *indirect routing*: communication from correspondent to mobile goes through home agent, then forwarded to remote
 - *direct routing*: correspondent gets foreign address of mobile, sends directly to mobile

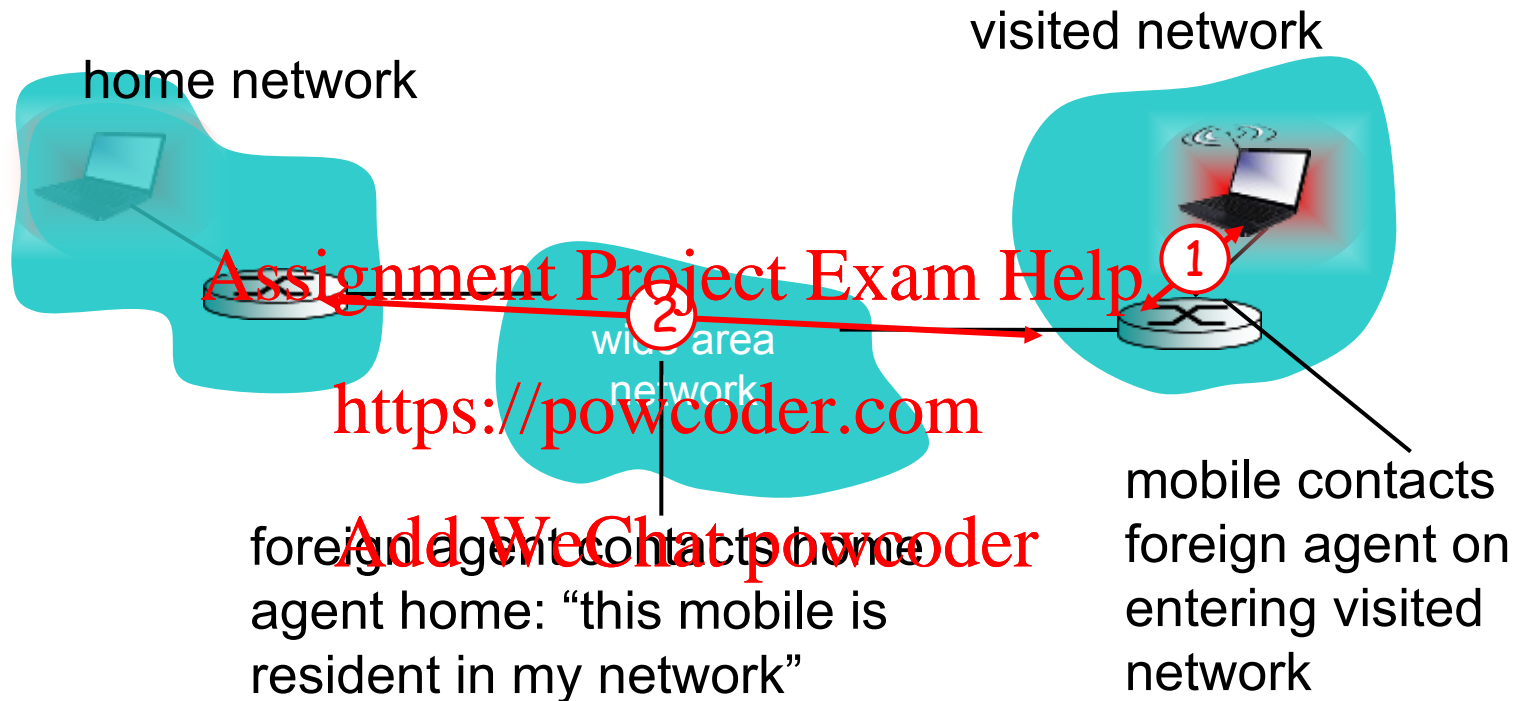


Mobility: approaches

- › *let routing handle it:* route to advertise permanent address of mobile-nodes-in-residence. Not scalable routing table exchange.
 - routing tables indicate where to millions of mobiles
 - no changes to end-systems
- › *let end-systems handle it:*
 - *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
 - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile



Mobility: registration

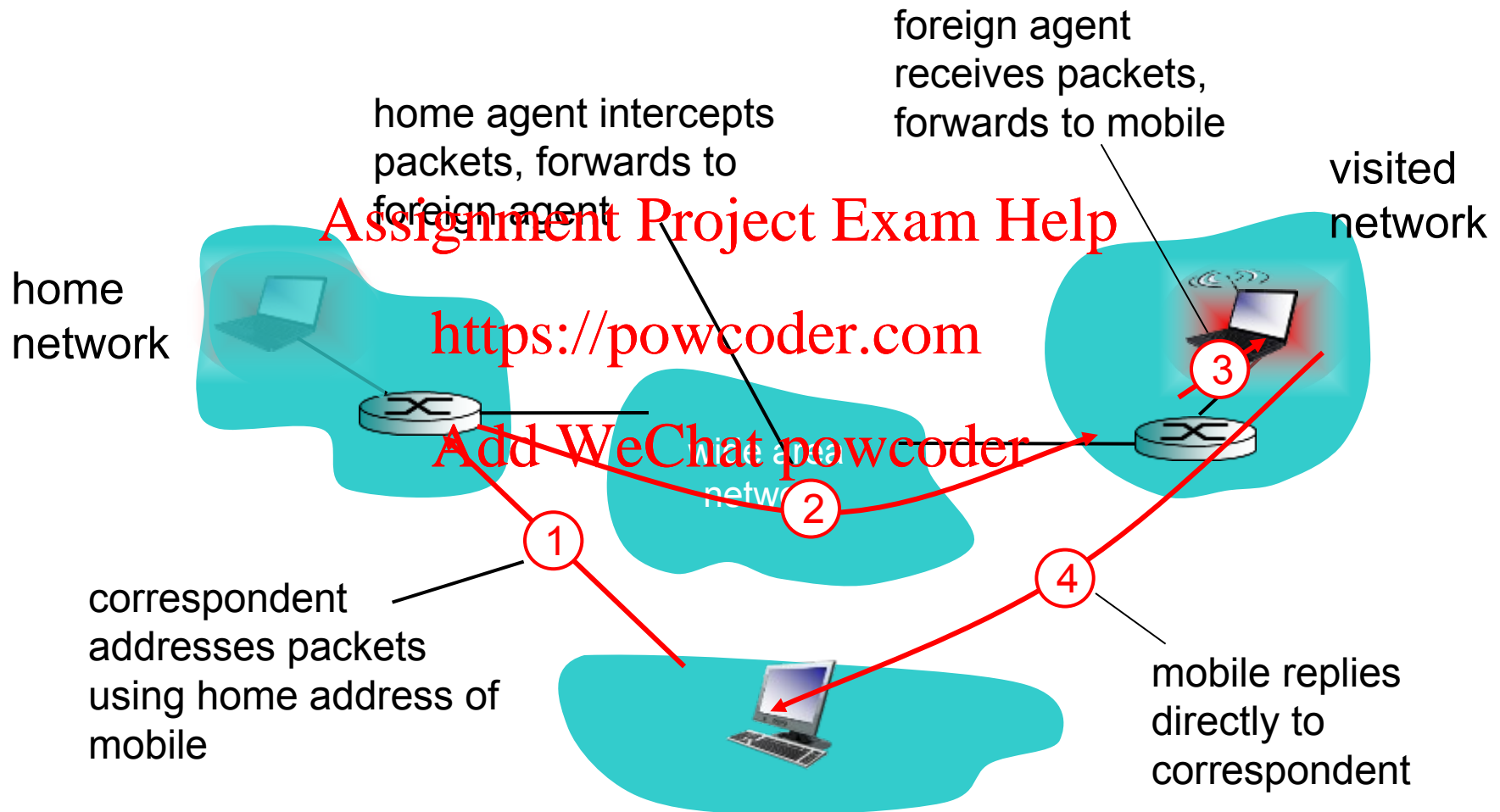


end result:

- › foreign agent knows about mobile
- › home agent knows location of mobile



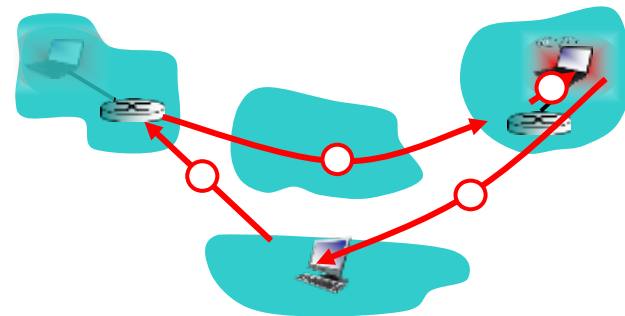
Mobility via indirect routing



Indirect Routing: comments

- › mobile uses two addresses:
 - **permanent address**: used by correspondent (hence mobile location is *transparent* to correspondent)
 - **care-of-address**: used by home agent to forward datagrams to mobile
- › **triangle routing**: correspondent-home-network-mobile
 - inefficient when correspondent, mobile are in same network

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Indirect routing: moving between networks

- › suppose mobile user moves to another network
 - registers with new foreign agent
 - new foreign agent registers with home agent
 - home agent update care-of-address for mobile
 - packets continue to be forwarded to mobile (but with new care-of-address)
- › changing foreign networks transparent: *on going connections can be maintained!*

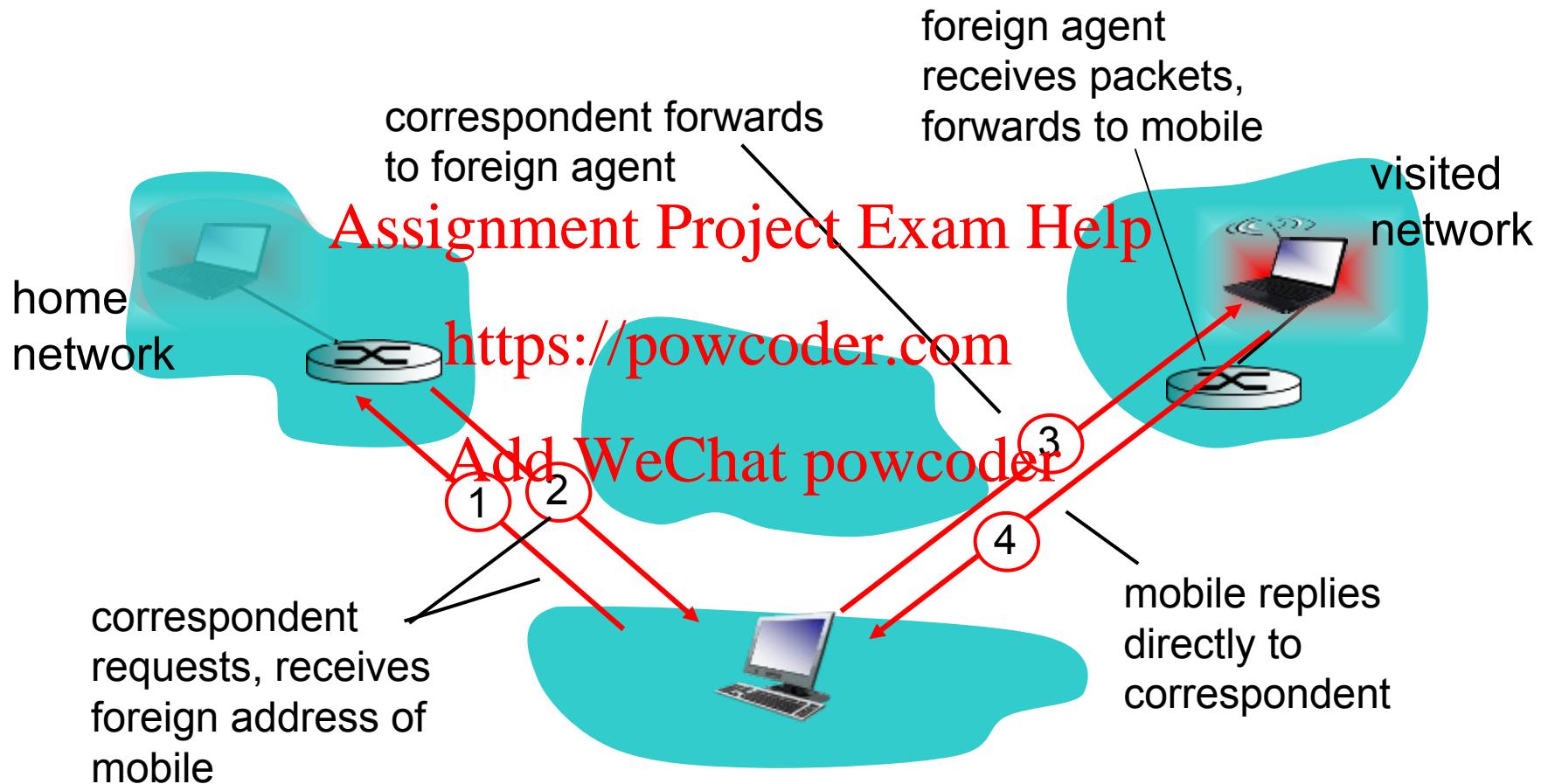
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Mobility via direct routing

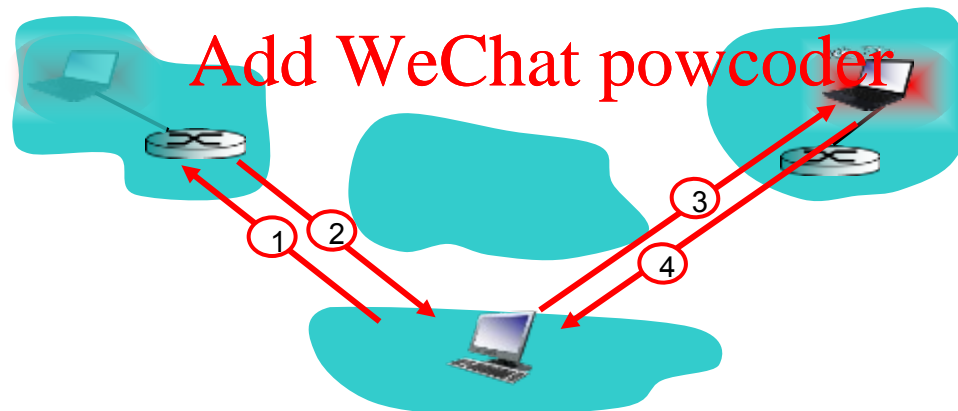


Mobility via direct routing: comments

- › overcome triangle routing problem
- › *non-transparent to correspondent*: correspondent must get care-of-address from home agent
 - what if mobile changes visited network?

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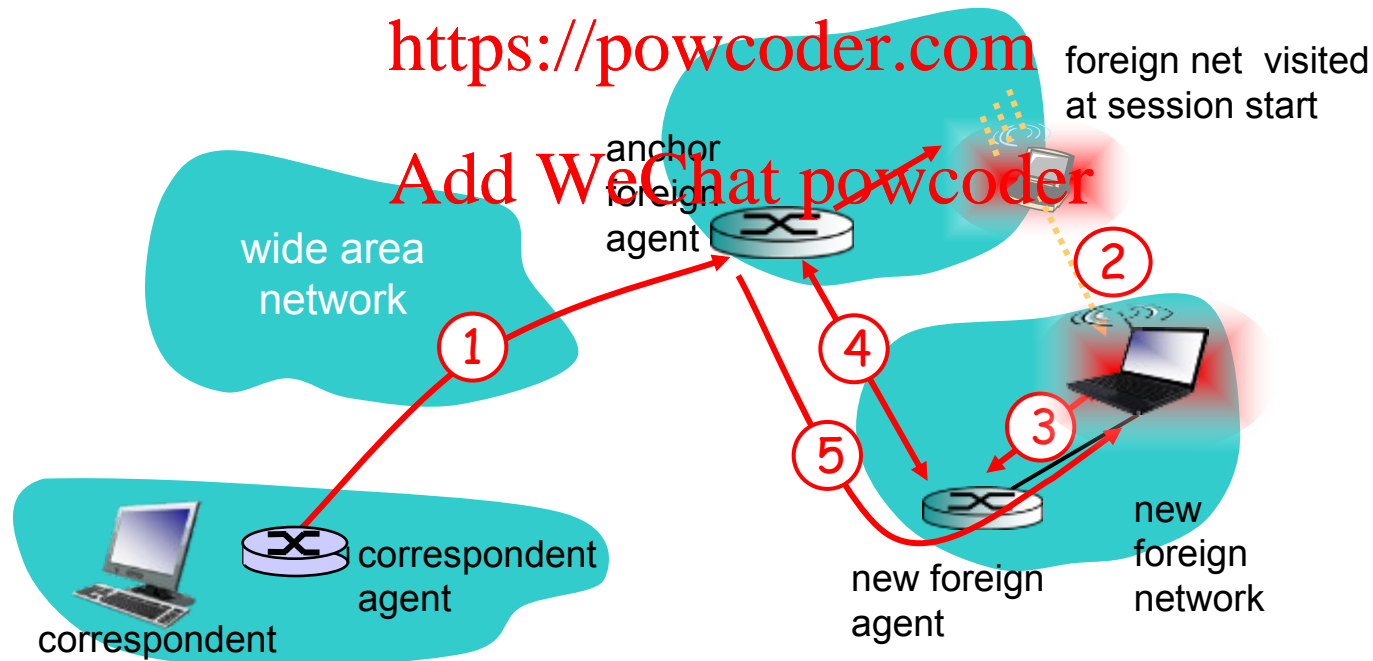


Accommodating mobility with direct routing

- › anchor foreign agent: FA in first visited network
- › data always routed first to anchor FA
- › when mobile moves: new FA arranges to have data forwarded from old FA (chaining)

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foreign net visited
at session start



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Mobile IP

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› RFC 3344

› has many features we have seen:

- home agents, foreign agents, foreign-agent registration, care-of-addresses

› three components to standard:

- indirect routing of datagrams
- agent discovery
- registration with home agent

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dest: 128.119.40.186	//
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```
dest: 128.119.40.186
```

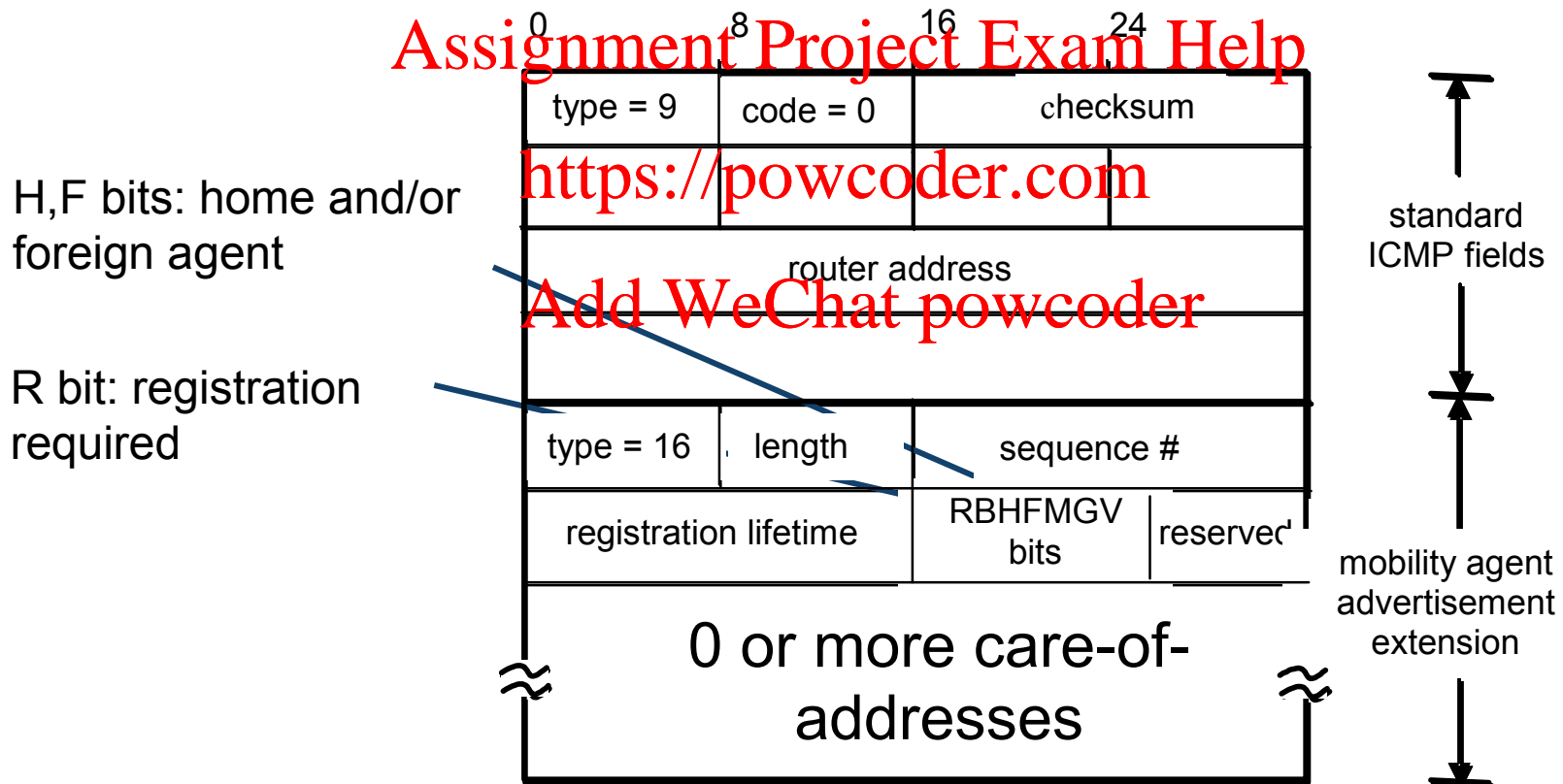
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dest: 128.119.40.186

packet sent by
correspondent

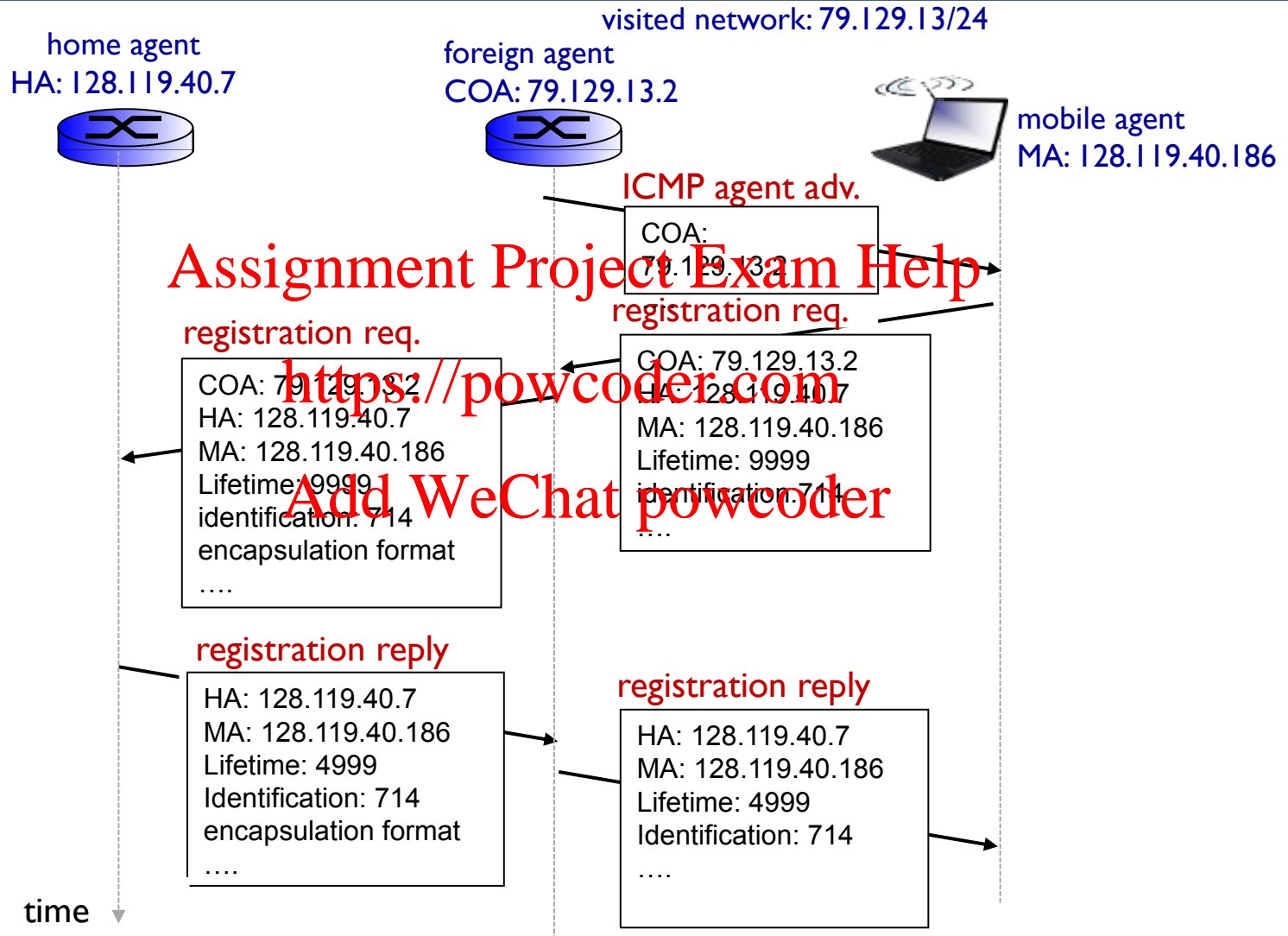
Mobile IP: agent discovery

- › *agent advertisement*: foreign/home agents advertise service by broadcasting ICMP (Internet Control Message Protocol) messages (typefield = 9)





Mobile IP: registration example





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Assignment Project Exam Help Mobility in Cellular Networks

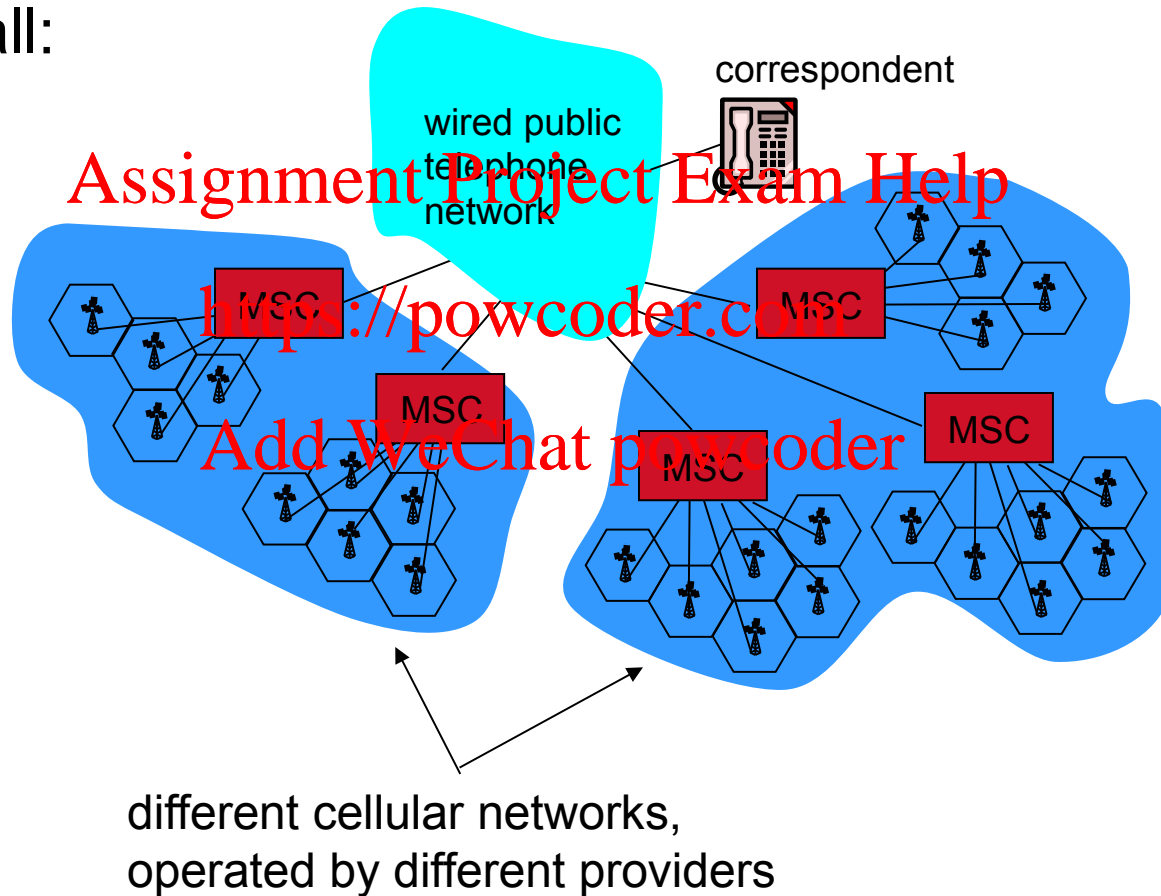
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Components of cellular network architecture

recall:





Handling mobility in cellular networks

- › *home network*: network of cellular provider you subscribe to (e.g., Vodafone)
 - *home location register (HLR)*: database in home network containing permanent cell phone #, profile information (services, preferences, billing), information about current location (could be in another network)
- › *visited network*: network in which mobile currently resides
 - *visitor location register (VLR)*: database with entry for each user currently in network
 - could be home network

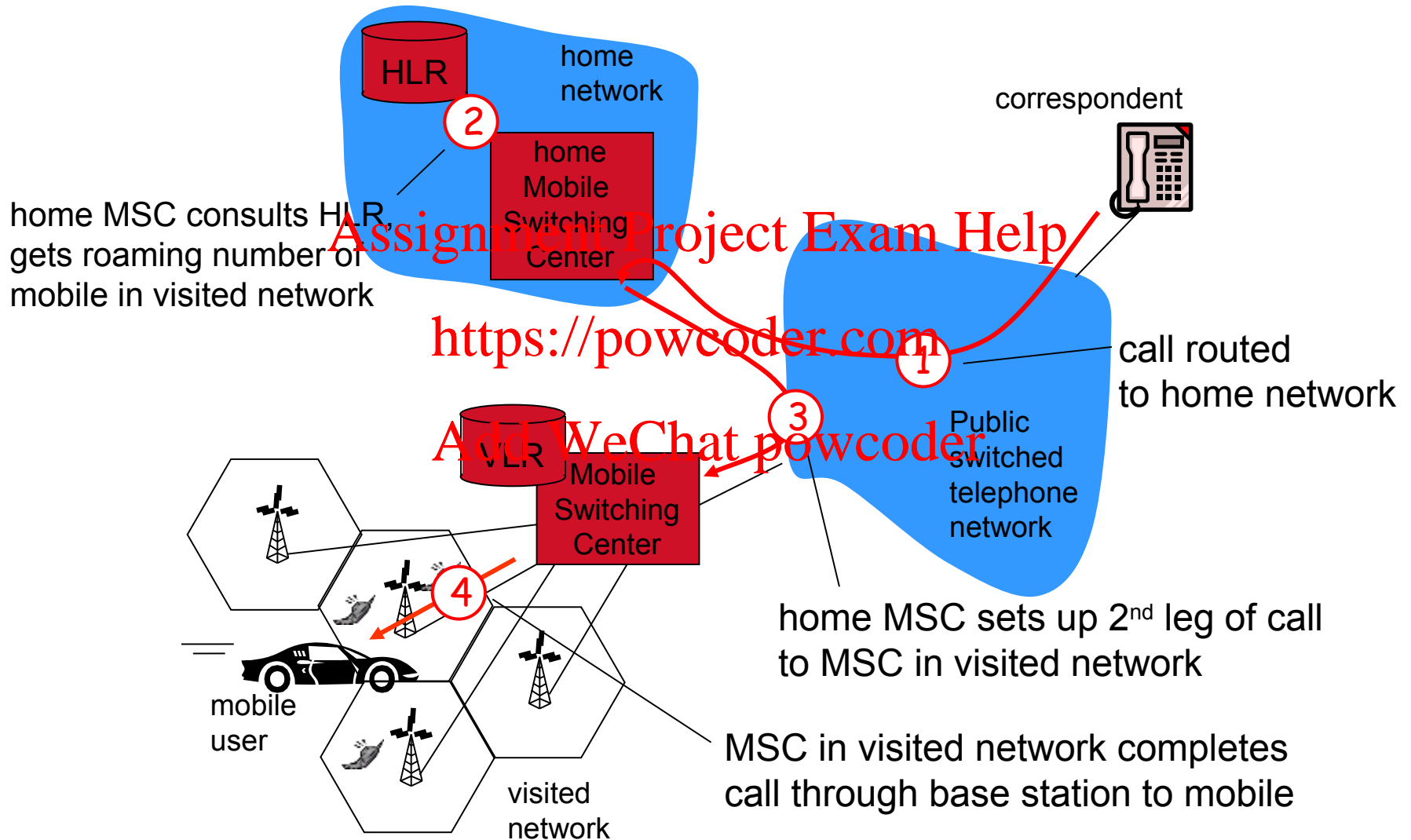
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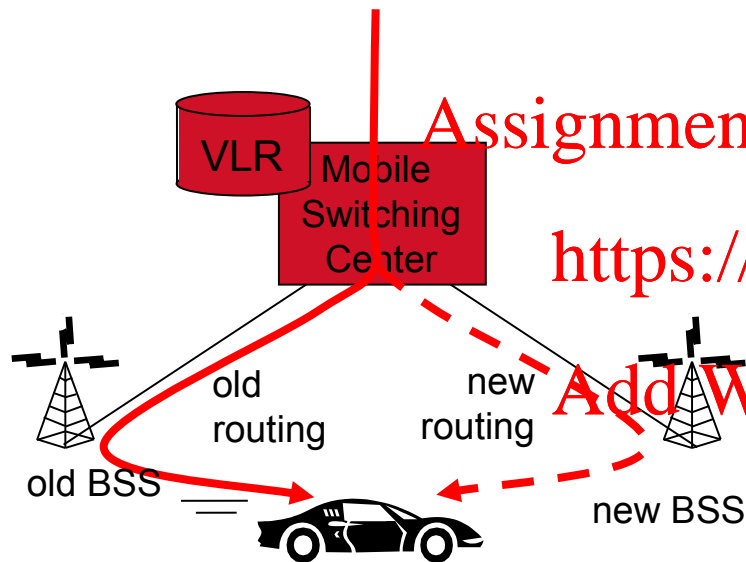


GSM: indirect routing to mobile





GSM: handoff with common MSC



› *handoff goal*: route call via new base station (without interruption)

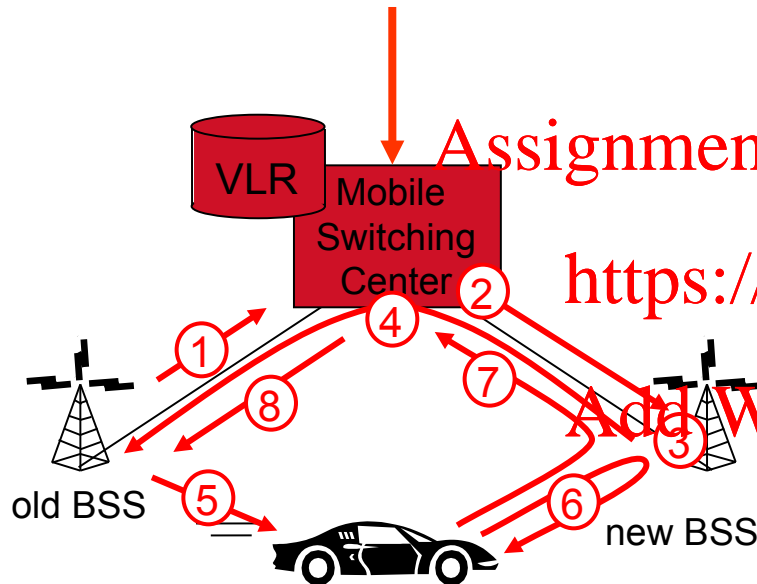
› reasons for handoff:

- stronger signal to/from new BSS (continuing connectivity, less battery drain)
- load balance: free up channel in current BSS

› handoff initiated by old BSS



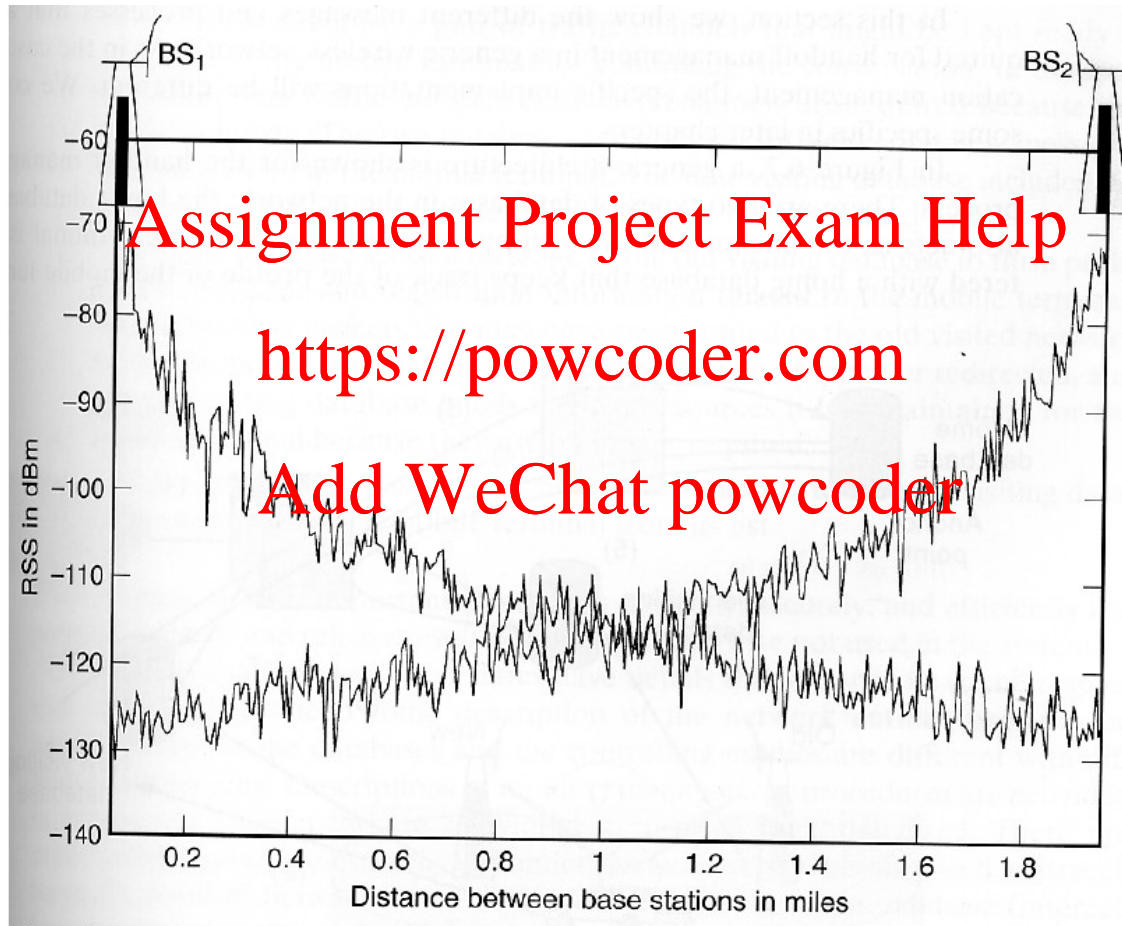
GSM: handoff with common MSC



1. old BSS informs MSC of impending handoff, provides list of 1+ new BSSs
2. MSC sets up path (allocates resources) to new BSS
3. new BSS allocates radio channel for use by mobile
4. new BSS signals MSC, old BSS: ready
5. old BSS tells mobile: perform handoff to new BSS
6. mobile, new BSS signal to activate new channel
7. mobile signals via new BSS to MSC: handoff complete. MSC reroutes call
8. MSC-old BSS resources released



Handoff algorithm: a brief overview



Signal Strength of Two Base Stations: when to handoff?



Handoff algorithm: a brief overview

- › Naive way: Compare the RSSs (Received Signal Strength) of two BSs
Handoff at

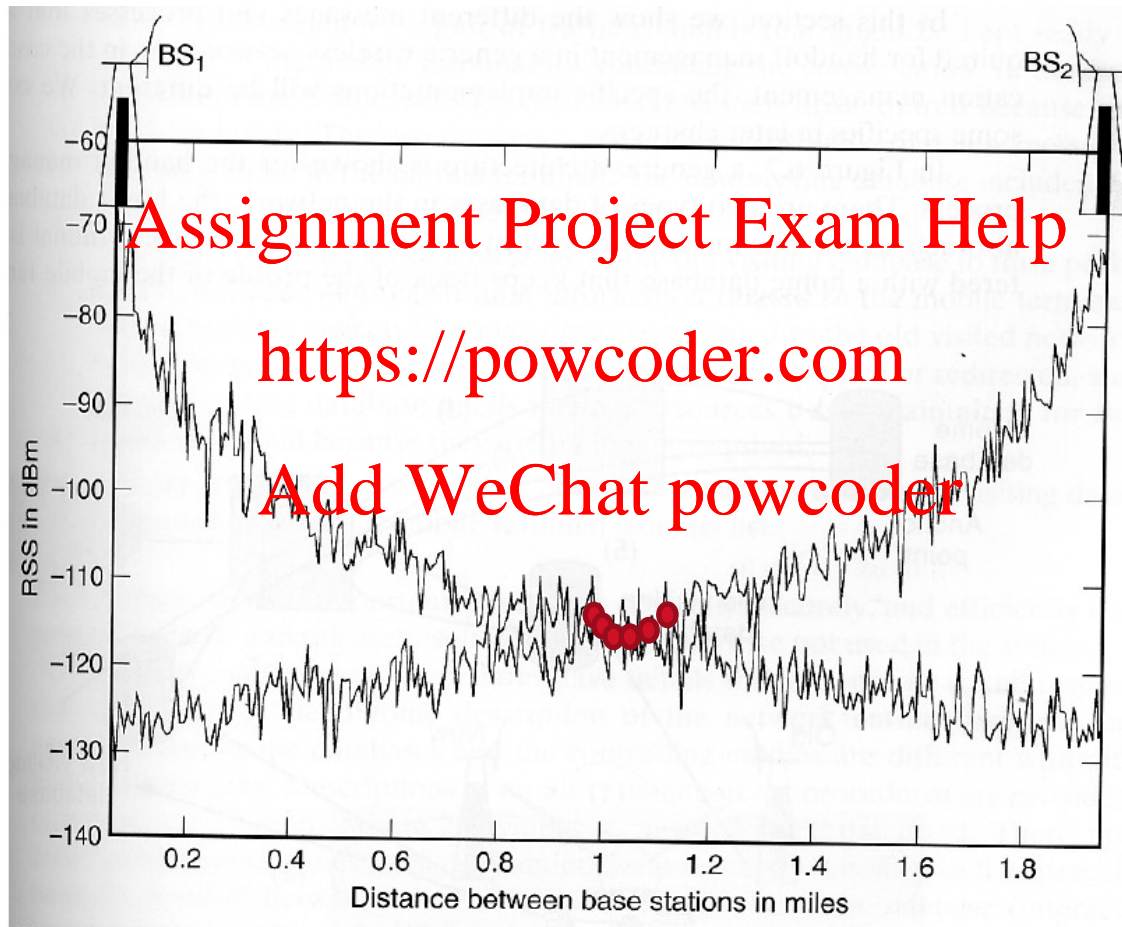
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Ping-pong effect



Handoff back and forth.

- › RSS: initiate handoff to BS new if

- › $P_{\text{new}} > P_{\text{old}}$

- › RSS with threshold(P_T): choose BS new if

- › $P_{\text{new}} > P_{\text{old}}$ and $P_{\text{old}} < P_T$

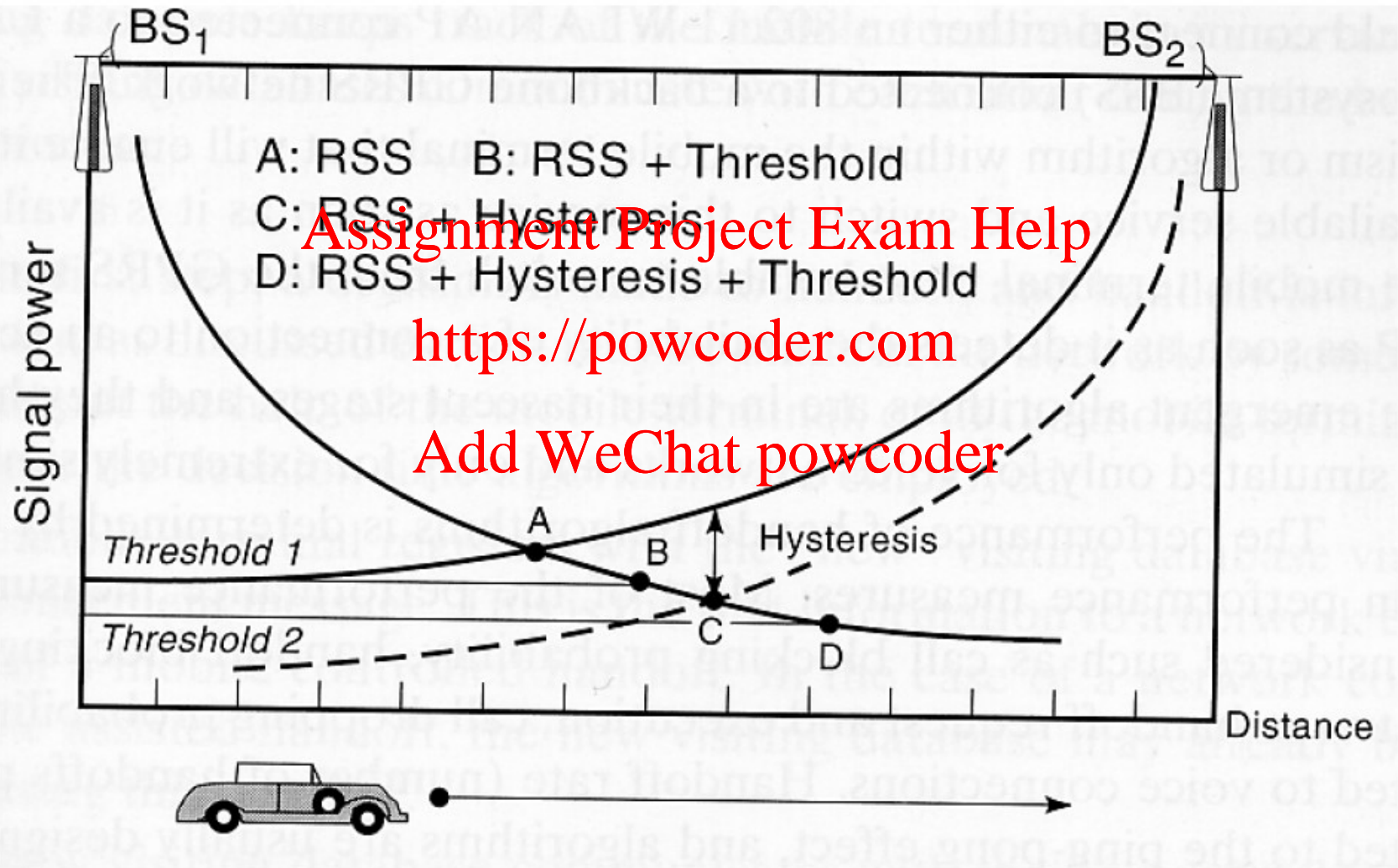
- › RSS with hysteresis(P_H): choose BS new if

- › $P_{\text{new}} > P_{\text{old}} + P_H$

- › RSS with threshold(P_T) and hysteresis(P_H): choose BS new if

- › $P_{\text{new}} > P_{\text{old}} + P_H$ and $P_{\text{old}} < P_T$

- › Even better: Add a **Dwell Timer** to the above algorithms: start timer when above condition is met; initiate handoff if condition persists when timer expires



Wireless, mobility: impact on higher layer protocols

› logically, impact *should* be minimal ...

- best effort service model remains unchanged
- TCP and UDP can (and do) run over wireless, mobile

› ... but performance-wise:

- packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and handoff
- TCP interprets loss as congestion, will decrease congestion window un-necessarily
- delay impairments for real-time traffic

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